Draba smithii Gilg ex O.E. Schulz (Smith's draba): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

February 3, 2004

Juanita A. R. Ladyman, Ph.D.
JnJ Associates
6760 S. Kit Carson Circle East
Centennial, CO 80122

Peer Review Administered by
Center for Plant Conservation

Ladyman, J.A.R. (2004, February 3). *Draba smithii* Gilg ex O.E. Schulz (Smith's draba): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/drabasmithii.pdf [date of access].

ACKNOWLEDGEMENTS

The time spent and help given by all the people and institutions mentioned in the References section are gratefully acknowledged. I would also like to thank the Colorado Natural Heritage Program, in particular Susan Spackman and David Anderson, and the Colorado Natural Areas Program, in particular Ron West, for their generosity in making their files and records available. I also appreciate access to the files and assistance given to me by Andrew Kratz, Region 2 Forest Service, and Chuck Davis, U.S. Fish and Wildlife Service. I also very much appreciate the documents sent to me by Michael Windham and Ann Kelsey of the University of Utah, Tim Hogan and Nan Letterer of the University of Colorado, and Ulrike Starck of the Botanischer Garten und Botanisches Museum Berlin-Dahlem. The thoughtful reviews and constructive comments of Beth Burkhart and two other unnamed reviewers are also much appreciated.

AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as Greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 11 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates*, an environmental consulting company in Colorado.

COVER PHOTO CREDIT

Draba smithii (Smith's draba). Photograph by author.

LIST OF ERRATA

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *DRABA SMITHII*

Status

Draba smithii (Smith's draba) is designated sensitive by the USDA Forest Service – Rocky Mountain Region. The NatureServe Global Rank for this species is globally imperiled, G2, and it is designated imperiled, S2, by the Colorado Natural Heritage Program.

Primary Threats

Draba smithii is vulnerable due to its limited geographic range, small numbers, and infrequent occurrence. The most significant threats to *D. smithii* appear to come from habitat modification. Several known occurrences are subject to threats from recreational hiking and from permanent habitat modification from development projects such as road construction. Modification of the hydrology of occupied habitat may also affect some populations. Livestock grazing, fire, and invasive weeds appear to be low-level threats at the current time. *Draba smithii* grows in rock cracks and crevices, and thus only the accessible occurrences are vulnerable to large herbivores. Its rocky habitat provides a natural refuge from fire, and weed invasions appear unlikely at the present time.

Primary Conservation Elements, Management Implications and Considerations

The majority of known *Draba smithii* occurrence sites (25 of approximately 27 occurrences) are on USDA Forest Service land. Therefore, management decisions made by that agency could have a substantial effect on the entire population. There are no formal, written management plans directly concerning *D. smithii*. There is a lack of information concerning its abundance, distribution, biology, and optimal management procedures. However, the information currently available suggests that it is likely to survive satisfactorily, especially if additional research and surveys are carried out so that some basic management strategies can be formulated. Current evidence suggests that seedling recruitment is infrequent and that seeds may have a restricted dispersal pattern. This may explain the species' rarity. The infrequency of suitable habitat niches may also contribute to its lack of abundance. The information currently available suggests that several populations are relatively secure because they occur in areas that are afforded protection either by their remote location or by a land use designation, for example within a designated wilderness area. However, under current regulations this species may not receive the priority for further study that would help ensure its long-term security. One reason to monitor and study this regional endemic species is that it appears to occupy a habitat that should be fairly resilient to most land use practices. If population trends show a decline or if a contraction of range is noted over several years, it may indicate a fundamental problem with the ecology of that particular region.

Table of Contents

EDITOR: Beth Burkhart, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Tables:

Figures:

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Draba smithii* (Smith's draba) is the focus of an assessment because it is an endemic sensitive species in USFS Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a regional forester because of a significant current or predicted downward trend in abundance or in habitat capability that would reduce its distribution (USDA Forest Service 1995)). A sensitive species may require special management so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Draba smithii* throughout its range, which is restricted to southern Colorado in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations, but instead it provides the ecological background upon which management must be based. It does focus on the consequences of changes in the environment that result from management (i.e. management implications). Furthermore, it cites management recommendations proposed elsewhere and, when those management recommendations have been implemented, the assessment examines their success.

Scope

The *Draba smithii* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature that is relevant to the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *D. smithii* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but it is placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. The assessment emphasizes the refereed literature because this is the accepted standard in science. Non-refereed literature and reports were used in this assessment because in some case they were the only sources of the information. While they were regarded with greater skepticism, many reports and non-refereed publications on rare plants are considered reliable and often represent 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a refereed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (for example, Natural Heritage Program and herbarium records) were important in estimating the geographic distribution and population sizes. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted more heavily than observations only.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). It is difficult to conduct critical experiments in the ecological sciences and often observations, inference, good thinking, and models must be relied upon to guide the understanding of ecological relations.

In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted approaches to understanding features of biology and are used in synthesis for this assessment.

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessments.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

In 1990 the U.S. Fish and Wildlife Service nominated *Draba smithii* as a Category 2 candidate for listing as threatened or endangered (U.S. Fish and Wildlife Service 1993). Category 2 candidates were "taxa for which information in the possession of the Service indicated that proposing to list as endangered or threatened was possibly appropriate, but for which sufficient data on biological vulnerability and threat were not currently available to support proposed rules" (U.S. Fish and Wildlife Service 1996). In 1996, the U.S. Fish and Wildlife Service discontinued the use of Category 2 as a species designation (U.S. Fish and Wildlife Service 1996). Under the revised Candidate List, only those species for which there is enough information to support an endangered or threatened listing proposal are included. These were formerly known as Category 1 Candidate Species. The U.S. Fish and Wildlife Service no longer identifies candidate species, such as *D. smithii*, which are rare but for which there is little information on population trend or vulnerability.

Draba smithii is designated sensitive by the USDA Forest Service, Rocky Mountain Region (USDA Forest Service 2003). The NatureServe Global Rank[1] is globally imperiled, G2, and National Heritage Status Rank is nationally imperiled, N2 (NatureServe 2002). It is designated imperiled, S2, within the State of Colorado by the Colorado Natural Heritage Program.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Draba smithii is known to occur on land managed by the U.S. Forest Service (25 of approximately 27 known occurrences; **Table 1**, **Figure 1**) as well as on private land. There are no formal management plans written that directly address *Draba smithii*. Therefore, current management of the species in an area is essentially subject to the individual land manager's personal knowledge, and the continuity of a management strategy, for example during staff turnover, is not assured.

Draba smithii is described in the sensitive plant guides developed to assist field crews in recognizing sensitive species on the Rio Grande National Forest (Erhard 1994) and the Pike and San Isabel national forests and Comanche and Cimarron national grasslands (Ryke et al. 1993). The single known occurrence on the San Juan National Forest (Occurrence 11; **Table 1**) is visited periodically to determine its presence, but the size and structure of the population is not formally monitored (Redders personal communication 2002). The most numerous occurrences have been reported on the Rio Grande National Forest. "The Revised Land and Resource Management Plan for the Rio Grande National Forest" (USDA Forest Service 1996) mentions general considerations applicable to all "species listed as TES or Colorado Natural Heritage

[1]For definitions of G and S ranking see Rank in the Definition section at the end of this document.

Table 1. Information for 27 *Draba smithii* occurrences in U.S. Forest Service Region 2. Includes occurrence number, Colorado county, location details, ownership, abundance, and observation date.

Arbitrary Occurrence No.	County	Location	Ownership	Abundance	Observation date	Sources of information[1]
1	Custer	On the Commanche Lakes Trail, west of Alvarado Campground, southwest of Westcliffe.	San Isabel National Forest	Unreported.	July 22, 1999	*Brian Elliott #9319* and *#9290* with E. Mark, RM. Elliott and Hartman 2000. Colorado Natural Heritage Program element occurrence records.
2		Music Pass.	Rio Grande National Forest	Unreported.	June 28, 1971	*Howard #2389* 1971, COLO. Colorado Natural Heritage Program element occurrence records.
3	Saguache	Deadman Creek, within the Sangre de Cristo Wilderness Area.	Rio Grande National Forest	4 isolated boulders each with 5 or more plants.	June 28, 1997	Colorado Natural Heritage Program element occurrence records.
4	Alamosa	Along Mosca Trail to Mosca Pass.	Rio Grande National Forest	Unreported.	June 10, 1998	*Charity Hall #292.1* with Brian Jacobs and Alex Morgan, RM. Elliott and Hartman 2000. Colorado Natural Heritage Program element occurrence records.
5		Mosca Creek, within the Sangre de Cristo Wilderness Area, adjacent to National Park Service land.	Rio Grande National Forest	Approximately 100 plants in 1999.	1999; 1973	Colorado Natural Heritage Program element occurrence records.
6		South of Great Sand Dunes at confluence Zapata Creek and California Gulch.	Rio Grande National Forest	Unreported.	July 25,1999	*Brian Elliott #9556*, RM. Elliott and Hartman 2000. Colorado Natural Heritage Program element occurrence records.
7		South Zapata Creek drainage.	Rio Grande National Forest	Unreported.	June 28, 1998	*Hogan #3338*, COLO. Colorado Natural Heritage Program element occurrence records.
8		South Zapata Creek drainage, west of California Gulch.	Rio Grande National Forest	Unreported.	June 28, 1998	*Hogan #3373*, COLO. Colorado Natural Heritage Program element occurrence records.
9	Las Animas	San Francisco Canyon (near Little Fishers Peak Mesa).	Private	Unreported.	July 11, 1938	*Rollins #1849* 1938 UC, RM, GH. Colorado Natural Heritage Program element occurrence records.
10		Fishers Peak Mesa.	Private	Unreported.	July 3, 1983	*Robertson #32* 1983, COLO. Colorado Natural Heritage Program element occurrence records.
11	Archuleta	East Fork of the San Juan River, near FS road 667.	San Juan National Forest	In 2002, several discrete patches of plants associated with boulders of bedrock/ cliffs. Plants ranged from one to approx. one dozen per "patch".	July 1, 1999	*King #sn.* 4 June 1999, COLO. Ladyman *#6-2-02-03* 2002 at KLM - Denver Botanical Garden. Colorado Natural Heritage Program element occurrence records.
12	Mineral	West-northwest of Wagon Wheel Gap, near Spring Gulch.	Rio Grande National Forest and private	Consists of 2 main sub occurrences (summarized by Colorado Natural Heritage Program 1998). It grows in small patches with greater than 300 individuals occupying a total of approximately 1 acre.	July 9, 1998; 1978	Colorado Natural Heritage Program element occurrence records.

Table 1 (cont.).

Arbitrary Occurrence No.	County	Location	Ownership	Abundance	Observation date	Sources of information[1]
13	Mineral	West-northwest of Wagon Wheel Gap.	Rio Grande National Forest and private	Unreported.	July 9, 1998; 1978	Colorado Natural Heritage Program element occurrence records.
14		West of Pool Table Road.	Rio Grande NF and private	5 individuals in one patch. Approx. 100 plants in 1/2 acre.	July 9, 1998	*Rondeau #98-048* with C. Cordova. COLO. Colorado Natural Heritage Program element occurrence records.
15		Wagon Wheel Gap.	Rio Grande National Forest (or private)	Unreported.	June 1875	*T. S. Brandegee #1071* GH. Hitchcock (1941).
16		On steep northerly slope in Wagon Wheel Gap.	Rio Grande National Forest (or private)	Unreported.	June 6, 1911	*Murdoch Jr. #4546* GH. Hitchcock (1941).
17		Along Deep Creek approximately 2 miles north of major confluence.	Rio Grande National Forest	Unreported.	July 28, 1998	Colorado Natural Heritage Program element occurrence records.
18		Bellows Creek.	Rio Grande National Forest and private	Unreported.	May 7, 1911	*Murdoch #4513* COLO, GH. Hitchcock (1941). Colorado Natural Heritage Program element occurrence records.
19		East Willow Creek, population likely extends into North Creede (see Occurrence 20 below).	Rio Grande National Forest and private	A total of four sections were surveyed. One observation in 1998 reported 750 or more individuals over an area of approximately 25 acres while a separate survey reported an additional approximate 200 plants.	August 9, 1998	Colorado Natural Heritage Program element occurrence records.
20		North Creede-West Willow Creek Area.	Rio Grande National Forest and private	Unreported.	August 9, 1998	Colorado Natural Heritage Program element occurrence records.
21		East of Deep Creek.	Rio Grande National Forest	100 individuals counted; estimate total population less than 1000 individuals.	July 27, 1998	Colorado Natural Heritage Program element occurrence records.
22		Near Dry Gulch.	Rio Grande National Forest	Common.	June 19, 1939	*Stewart #178* 1939, COLO. Colorado Natural Heritage Program element occurrence records.
23		Slopes of Rat Creek and Kettle Ponds.	Rio Grande National Forest and private	200 individuals occupying less than 5 acres.	July 27, 1998	Colorado Natural Heritage Program element occurrence records.
24		West Bellows Creek, above West and East Bellows Creeks confluence.	Rio Grande National Forest	Estimate greater than 100 individuals over a linear 0.5 mile of trail.	July 12, 1998	Colorado Natural Heritage Program element occurrence records. COLO specimen: *R.J. Rondeau #98-053*. With G. Doyle and C. Cordova.

Table 1 (concluded).

Arbitrary Occurrence No.	County	Location	Ownership	Abundance	Observation date	Sources of information[1]
25	Saguache	Lake Fork, southwest of Comanche Peak.	San Isabel National Forest	Common.	June 23, 1992	*Hogan #1841* 1992. COLO. Colorado Natural Heritage Program element occurrence records.
26		On summit ridge of Kit Carson Mountain between Copper Gulch and Spanish Peak (head of Spanish Creek; possibly in Sangre de Cristo Wilderness).	Rio Grande National Forest	Locally common. 50 individuals were counted in one area with additional scattered individuals. Plants forming tight mats.	July 14, 1991	*Yeatts #3036* 1991, at KLM - Denver Botanical Garden.. Colorado Natural Heritage Program element occurrence records.
27		Mt. Baldy. [The location most closely matching the 1891 collection site is Baldy Alto, elevation 13,698 feet, located in La Garita Wilderness Area approximately 10 miles north of Creede (Colorado Native Plant Society 1997).	Gunnison National Forest	Unreported	1891	E.C. Smith collector. Holotype in the Herbarium at Botanic Garden and Botanical Museum Berlin-Dahlem. Schultz (1927), Hitchcock (1941).

[1] COLO = Herbarium at the University of Colorado, Boulder, Colorado.

GH = Gray Herbarium, Harvard University, Cambridge, Massachusetts.

RM = Rocky Mountain Herbarium, University of Wyoming, Laramie, Wyoming.

UC = Herbarium at the University of California, Berkeley, California.

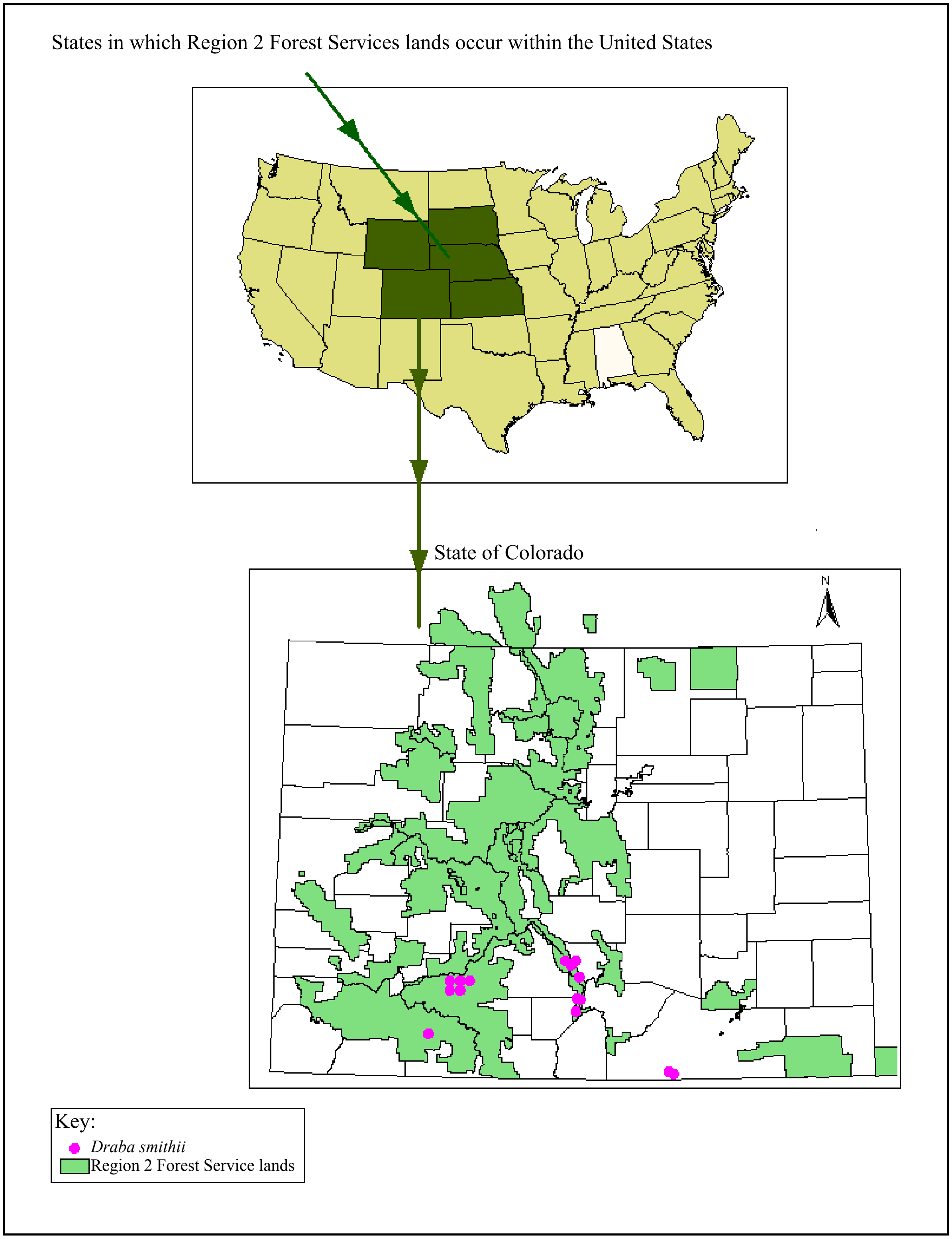

Figure 1. Approximate occurrence locations of *Draba smithii* demonstrating its global range (one point on the map may indicate one or more occurrences).

Program Species of Concern”, but it makes no specific mention of *D. smithii*.

At least two occurrences of *Draba smithii* are in designated wilderness areas: the La Garita Wilderness that straddles the Gunnison and Rio Grande national forests and the Sangre de Cristo Wilderness that is part of the Rio Grande and San Isabel national forests. A designated wilderness area is managed to “retain its pristine character and natural processes, with minimal evidence of human influence” (USDA Forest Service 1996). Wilderness areas are closed to motorized vehicles, and only foot and horse traffic are permitted. Even though these restrictions reduce the potential for disturbance, wilderness recreational use can be expected to rise during the next decade (USDA Forest Service 1991). Therefore, the impacts of foot traffic depend upon a population’s proximity to hiking paths. Livestock grazing is permitted within wilderness areas, and grazing use is expected to remain at current levels within the foreseeable future (USDA Forest Service 1991). Livestock grazing is expected to impact relatively few occurrences because at the current time *D. smithii* is understood to primarily grow in talus, boulder, and bedrock habitats.

Biology and Ecology

Classification and description

Systematics and synonymy

Draba is the largest genus of the Brassicaceae or Cruciferae family, commonly known as the mustard family. *Draba* species are found almost worldwide in relatively cool habitats at either high elevation or high latitude. There are approximately 350 species worldwide and 104 throughout Central and North America (Rollins 1993). *Draba smithii* has no synonyms and is accepted as a unique taxon. Because of its short, dense, uniformly branched trichomes and its white flowers, *D. smithii* is distinct from other American species (Hitchcock 1941).

History of species

Draba smithii was first collected in Colorado by T.S. Brandegee in June 1875 *(Brandegee #1071* GH). Ernst Gilg and O.E. Schulz described it as a new species in 1927 and named it for E.C. Smith who collected it on “Mt. Baldy” at 12,000 ft. in Colorado in 1891 (Schulz 1927). The location most closely matching the 1891 collection site is Baldy Alto (Occurrence 27; **Table 1**), elevation 13,698 feet, located in La Garita Wilderness Area approximately 10 miles north of Creede (Colorado Native Plant Society 1997). Early herbarium specimens had often been misidentified, but through the efforts of C. Leo Hitchcock in 1939 many specimens from historical collections were correctly renamed.

Non-technical description

Draba smithii is a slender perennial from a many-headed (multicipital) caudex with prostrate, slender, and matted branches (Hitchcock 1941, Rollins 1993). The leaves are elongated-egg to stretched-oval (obovate to linear-oblanceolate) in shape. The leaves in basal tufts are less than 1 cm to as much as 2.5 cm long and 2 to 5 mm broad. There are 3 to 8 smaller leaves on the stem. The flowering stems are generally 10 to 15 cm long. The whole plant, including the pedicels (flower stalks), is grayish in color with dense, short, much branched hairs. An unusual characteristic of this plant is that there are no unbranched hairs present on any part of it. There are 20 to 30 (or more) white flowers on each stem, and the flower stalks are as much as 1 cm long. The fruits (siliques) are compressed, usually twisted, and 5 to 9 mm long and 2 to 2.5 mm broad. They are covered by fine stellate, or star-shaped, hairs. The seeds are approximately 1 mm long. Two forms of the plant have been described: a smaller mat form and a shade form that has a looser morphological appearance (*Johnston and Lucas #1812*, COLO). When making field identifications, it is particularly useful to remember that there are these two forms.

References to technical descriptions, photographs and line drawings

Technical descriptions are in Hitchcock (1941), Harrington (1964), Rollins (1993), and Weber and Wittman (2001a and 2001b). The technical description by Rollins (1993) is particularly complete. A description and photographs of flowering and fruiting live plants are published in Colorado Native Plant Society (1997). A description, photographs of individual plants and habitat, and a line drawing are also published in Spackman et al. (1997). An illustration of *Draba smithii* is provided in **Figure 2**. The holotype collected by O.E. Smith on Mt. Baldy in 1891 is located at the Botanic Garden and Botanical Museum Berlin-Dahlem, Germany.

Distribution and abundance

Draba smithii is known from Alamosa, Archuleta, Custer, Las Animas, Mineral, and Saguache counties in southern Colorado (**Table 1**; **Figure 1**). It is very sparsely

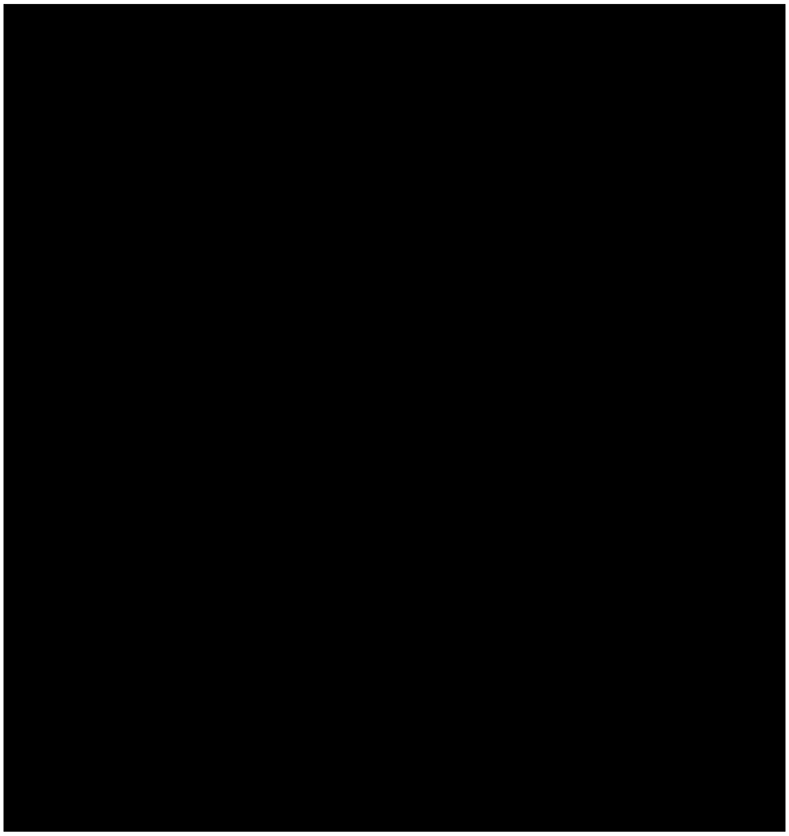

Figure 2. Illustration of *Draba smithii*. Illustration by Janet Wingate, used with permission.

distributed within a total range of approximately 3,800 square miles. It is "locally abundant" in some years. However, it has a patchy distribution and is not found in all areas that appear to have potential habitat. In this case "potential habitat" has not been critically defined and is used to describe habitat that from casual observation appears to be suitable for *D. smithii*. Plants have not been found in New Mexico, although one occurrence has been found within 12 miles of the state line (Colorado Native Plant Society 1997). Occurrences are on land managed by USDA Forest Service (specifically the Rio Grande, San Juan, San Isabel, and Pike national forests) and on private land. A historic and ambiguous occurrence site was likely on the Gunnison National Forest. The majority of occurrences are located on land managed by USDA Forest Service – 25 of approximately 27 occurrences. Occurrence sites are listed in **Table 1**.

Draba smithii is known from approximately 27 occurrences in Colorado, 19 of which have been found within the last fifteen years (**Table 1**). However, many occurrences are associated with imprecise location information. Several of the more recent occurrences that were described to the nearest section were counted as discrete occurrences, for example Occurrences 7 and 8 and Occurrences 13 and 14, if the habitat descriptions suggested different areas were visited. However, some sites may have been actually overlapping and the number of occurrences would then be fewer than 19. In this report, an occurrence is considered to be a population, and one occurrence of *D. smithii* usually consists of several patches that may be up to 100 m apart. An occurrence may also consist of several sub-occurrences that are more than 100 m apart. A sub-occurrence is equivalent to a sub-population, which means that interaction, through pollination or seed dispersal, is believed to occur between discrete sub-occurrences. However, without knowing the seed dispersal range and the pollination biology it is very difficult to delineate what comprises a single population. For example, the individuals in Occurrence 12 are distributed over three sections (Colorado Natural Heritage Program element occurrence records). There is currently insufficient information to determine whether these sub-occurrences are genetically linked or if some of them are actually genetically isolated.

Occurrence sizes range from less than ten to an estimated 1000 individuals per occurrence. Examples of occurrence size include an estimated 750 individuals over 25 acres, approximately 100 individuals over a linear distance of 0.5 miles, and isolated patches of approximately five individuals per patch on each of four boulders. In some instances the numbers of stems have been reported, for example 200 stems over 5 acres. Because of the growth habit of the multicipital caudex, stems are not equivalent to individuals and the number of plants may be significantly less.

Occurrence data have been obtained from the Colorado Natural Heritage Program, the Colorado Natural Areas Program, San Juan College Herbarium, Colorado State University Herbarium, the Rocky Mountain Herbarium, the Kathryn Kalmbach Herbarium, The Gray Herbarium at Harvard University, the University of Colorado Herbarium, Hitchcock (1941), and Elliott and Hartman (2000).

Population trend

Draba smithii was first collected in the Wagon Wheel Gap area in 1875 (*Brandegee #1071*, Gray Herbarium). Since then there have been at least five observations of occurrences in the same general area. However, there are insufficient numerical data in the literature, associated with herbarium specimens, or at the Colorado Natural Heritage Program to definitively determine a long-term population trend for *D. smithii*.

No monitoring activities have been carried out, and frequently the numbers of individuals were rarely counted or even estimated when populations were found and specimens were collected. There are only a few occurrences that have apparently been visited more than once. Specifically, three occurrences have been visited more than once. One was first visited in 1978 and again in 1998, another was visited in 1973 and again in 1999, and a third that was first located in 1999 was revisited in 2002. Only the species' presence at each visit was noted, but these observations indicate a persistence of populations once established. However, whether the populations are declining, stable, or increasing is unknown. In the area visited in 1978 and again in 1998, there appear to be several discrete sub-occurrences that may be part of the same population: one on a steep talus slope and the others in cracks on a basalt cliff where *Draba smithii* was associated with *Cryptantha weberi* (Colorado Natural Heritage Program occurrence record for *Cryptantha weberi #002*). It is unclear if these are part of the same population or if one or all of the sub-occurrences are persistent.

Habitat

Draba smithii occurs in the Southern Rocky Mountain Province (McNab and Avers 1994) in montane and mountain shrub zones (Johnson 1987). Historical occurrence information indicates that it also grows at or above the tree line (Schulz 1927). It grows on rock outcrops and on talus slopes with little closely-associated vascular vegetation, although frequently the rocks are covered by abundant lichen and, in some cases, mosses. Photographs of the plant and its habitat in Archuleta County, Colorado are shown in **Figure 3a** and **Figure 3b**.

Draba smithii's range is essentially within the region having a 15 to 30 inch average annual rainfall and a 32 ^{o}F to 45 ^{o}F mean annual temperature range (Bailey et al. 1994). Environmental parameters will be affected by elevation with wetter, cooler conditions at higher elevations. *Draba smithii* occurs at elevations from 2,365 m to approximately 4,000 m (7,760 to 13,123 ft.), with the majority of occurrences between 2,500 and 3,299 m (**Figure 4**). Elevation was not reported for all occurrences. Where plants were found within a range of elevations, the maximum and minimum values were included in the analysis. Plants are found on slopes of approximately 30 percent incline to sheer rock faces, where they occur in cracks and ledges. They have been found on slopes facing south, southwest, southeast, and west-southwest. Although one old reference to habitat does mention an occurrence on a northerly slope, this is subject to interpretation, and north or northerly aspects have not been recorded recently.

Draba smithii occupies both sunny and shady sites. Shady sites are likely preferred as even in sunny sites plants are often in crevices or are partially shaded by rock ledges and boulders. Although many habitats are described as xeric, plants have been also been reported to occur in seasonal seep areas and moist rock outcrops in aspen stands. *Draba smithii* occurs on quartz porphyry and volcanic-derived soils, including pre-ash-flow andesitic lavas, breccias, tuffs, and conglomerates (Tweto 1978). Subtleties in the moisture conditions, for example seasonal wetness or water collection sites, might contribute to the patchy and rare nature of *D. smithii*. A correlation between occurrences and volcanically derived soils has been noted, and suggestions were made to direct survey efforts in the San Juan volcanic field, the volcanic hills in the San Luis Valley, and on the dikes associated with the Spanish Peaks (Colorado Native Plant Society 1997). It

Figure 3a. View of *Draba smithii* growing in rock crevices (photograph by J.A.R. Ladyman). The creamy white-colored flowers are *Draba smithii* and the yellow flowers are *Mimulus* sp.

is notable that moisture is frequently more available for plants in lava flows as compared to "adjacent non-lava land" (Dick-Peddie 1993).

Although directly part of the sparse vegetation of rock dwelling communities, *Draba smithii* grows in various douglas-fir (*Pseudotsuga menziesii*), blue spruce (*Picea pungens*), bristlecone pine (*Pinus aristata*), and aspen (*Populus tremuloides*) communities. In one case, a population was found associated with thin-leaf alder (*Alnus tenuifolia*) and a species of willow (*Salix* spp.). Other communities in which *Draba smithii* occurs include *Pinus aristata*/*Festuca arizonica* (bristlecone pine/Arizona fescue), Arizona fescue grassland, and pinyon juniper woodland. The habitat conditions reported for each occurrence site are summarized in **Table 2**.

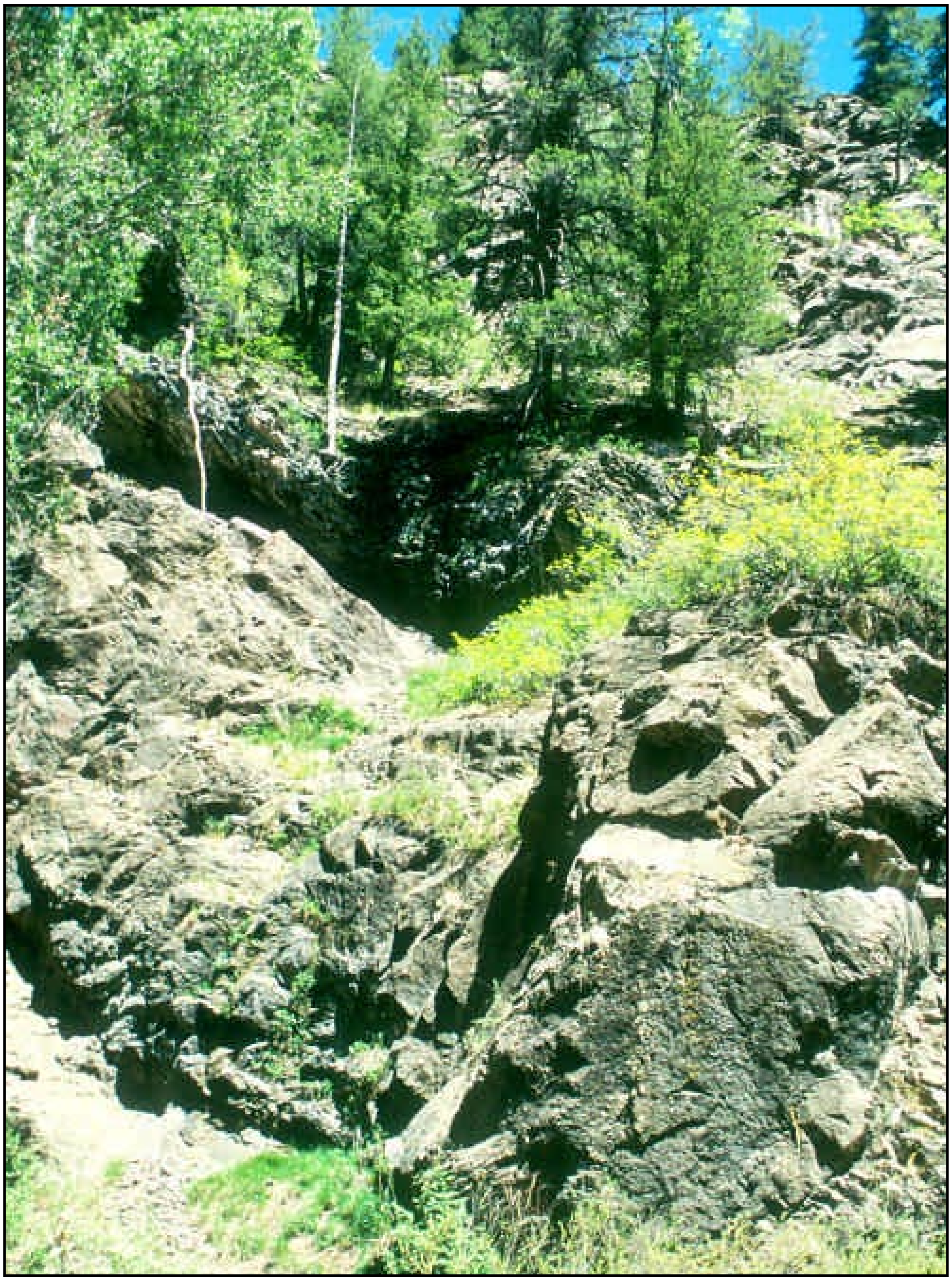

Figure 3b. View of *Draba smithii* habitat (photograph by J.A.R. Ladyman).

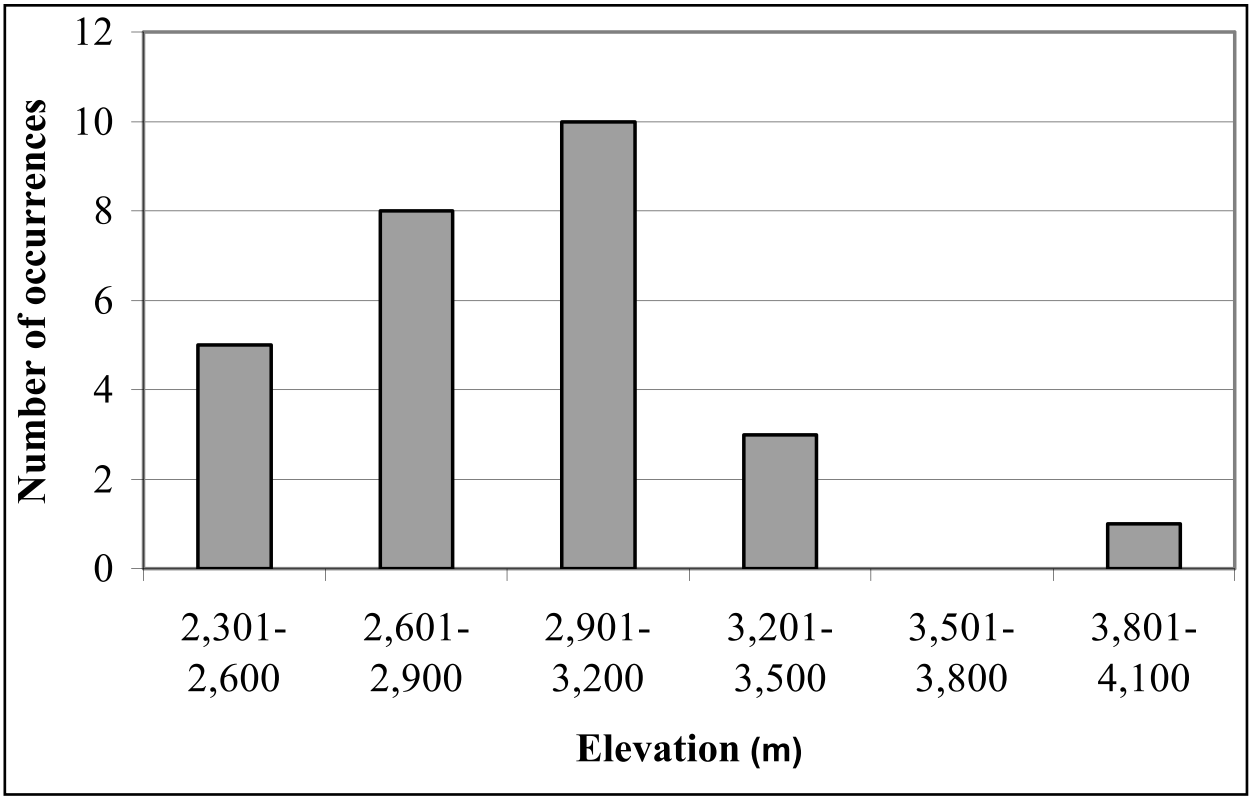

Figure 4. Graphic representation of the elevation distribution of *Draba smithii* populations. The figure does not include occurrences where elevation was not reported.

Associated vascular species are listed in **Table 3**. The non-vascular associates, for example mosses and lichens, have not been examined. One moss in close association with *Draba smithii* was identified as *Brachythecium fendleri* (Allred personal communication 2002, Weber personal communication 2002). *Brachythecium fendleri* grows on fine soils that accumulate in rock cracks and crevices. Lichens, algae, mosses, liverworts and ferns frequently comprise early successional vegetation of exposed rock sites (Dick-Peddie 1993), and *D. smithii* most likely represents a species of a later successional stage in its narrow habitat.

Reproductive biology and autecology

Draba smithii flowers from May into August and silique fill (fruiting) begins in June, or even late May in some years. The periods of flowering and fruiting appear to vary from year to year and likely depend upon weather conditions. The earliest date fruits have been reported is June 2, in a year when the preceding spring and winter were exceptionally dry, and the latest time flowers have been observed is August 9. Many observations, as judged by the number of flowering and/or fruiting stems, indicate that the species is successfully reproducing (Colorado Natural Heritage Program element occurrence data 2002 and herbarium records; see Distribution and Abundance section for list of sources). However, seedlings have not been reported. Seedlings are likely to be very inconspicuous, so it is not clear if they are actually absent or merely unnoticed.

Draba smithii reproduces sexually, although it is not clear whether it is self- or cross-pollinated (Windham personal communication 2002). Self-compatible inbreeders and self-incompatible outbreeders are all known within the genus, and occasional outcrossing may occur in many mainly self-pollinating *Draba* species (Mulligan 1970, Mulligan and Findlay 1970). Chromosome studies of this species indicate that it is a tetraploid, with n = 16 in meiotic cells (Windham personal communication 2002). Of the North American *Drabas*, the white-flowered euploid species with chromosome numbers based on x = 8 (such as *D. smithii*) appear most closely related to European and Asian *Drabas* (Mulligan 1976, Windham 2000). The chromosome number of *D. smithii* is the same as that of another leafy-stemmed, white-flowered species from Canada, *D. incana*, which is a self-compatible inbreeder (Mulligan 1970). Schulz (1927) assigned *D. smithii* and 28 other species that are distributed as far apart as the

Table 2. Habitat information for 27 *Draba smithii* occurrences in U.S. Forest Service Region 2.

Arbitrary Occurrence No.	County	Observation Date	Habitat summary from herbarium records, Colorado Natural Heritage Program element occurrence records and the literature (see text).
1	Custer	July 22, 1999	*Populus tremuloides* and *Picea englemannii* with *Abies lasiocarpa*.
2		June 28, 1971	No information.
3	Saguache	June 28, 1997	Dominant plant association is *Cercocarpus montanus/Muhlenbergia montana*. Individuals occur under boulders on south side of a creek that is shady in summer but likely sunny in winter. The south facing slopes are dry with juniper and *Pinus edulis* whereas the north-facing slopes are either dominated by aspen or conifers. The creek itself is an aspen/mesic forb, aspen/*Acer glabrum* riparian community. Elevation 10,300 to 10,400 ft.
4	Alamosa	June 10, 1998	No information.
5		1973; 1999	In 1973 plants were reported growing on a rocky hillside. Elevation 7,500 ft. In 1999 plants were reported growing in rock cracks on steep, shaded south slope. The rocks on the slopes were of volcanic origin and there was little competing vegetation.
6		July 25, 1999	*Picea englemanii* and *Populus fremontii*.
7		June 28, 1998	Subalpine spruce forest. Among rocks with *Cryptogamma acrostichoides*. 11200 ft (3414 m).
8		June 28, 1998	Rocky ledge in dry aspen forest. 10250 ft (3124 m).
9	Las Animas	July 11, 1938	Plants forming tangled mats in the crevices of rocks, vertical cliffs on the north slope of Raton Mesa.
10		July 3, 1983	Individuals growing above caprock, at or above the aspen zone, in open dry sites.
11	Archuleta	July 1, 1999; 2002	In 1999 the associated species were *Cornus stolonifera*, *Salix* spp., *Alnus incana*, *Pseudotsuga menziesii*, *Picea pungens*. Plants were found in cliff and canyon habitat on south- and west-facing slopes of 60 to 100% in partial shade and open exposures. Plants were found at sites with seasonal seepage. The rock parent material was San Juan volcanics. Individuals were found on cliff and talus slopes at 7760 ft. In a second report in 1999 individuals were found on a cliff face and talus slope with *Cornus stolonifera*, *Alnus incana*, *Pseudotsuga menziesii*, *Picea pungens*, *Salix* spp. at 7750 ft. In 2002 the habitat characters were similar to those described in 1999. In addition to moist sites where plants were found to be growing along side *Mimulus* spp., individuals were also observed at relatively xeric sites.
12	Mineral	1978; July 9, 1998	Plants on south-facing cliffs in broken basalt above a river. The slopes above and below the cliffs are dominated by Arizona fescue grasslands with scattered shrubs, including *Ribes* and *Symphoricarpos*. Associated species include *Geranium caespitosum*, lichen covered rock, moss, *Gilia penstemonoides* and *Cryptantha weberi*.
13		1978; July 9, 1998	In 1978, plants on steep talus slope and small benches below vertical cliffs with a west-southwest aspect. Plants were in protected gullies (where plants were mat-forming) and protected by large talus blocks (where plants were shaded from). Elevation was 2590 to 2620 m.
14		July 9, 1998	Growing in cracks of west-facing basalt cliffs and at base of basalt cliffs. Dominant plant community Arizona fescue (*Festuca arizonica*) grassland. Associated species included *Gilia penstemonoides*. The slope is 60% with 3/4 sun exposure in xeric clay soil at 8500 to 9200 ft.
15		June 1875	No information.
16		June 6, 1911	In crevices of rocks on steep northerly slope in Wagon Wheel Gap. Quartz porphyry.

Table 2 (concluded).

Arbitrary Occurrence No.	County	Observation Date	Habitat summary from herbarium records, Colorado Natural Heritage Program element occurrence records and the literature (see text).
17	Mineral	1940; July 28, 1998	In 1940 plants were observed in canyons with long talus slopes and on rhyolite cliffs at 9,200 to 10,800 ft. Plants were at sites with south, north, and east aspects. In 1998 plants observed on cliffs, at base of cliffs and on talus slopes. Total tree cover was 20% (*Pinus aristata* 20%, *Populus tremuloides* 1%, *Picea pungens* 1%) total shrub cover 10% (*Ribes cereum* 5%, *Rosa woodsii* 2% *Chrysothamnus nauseosus* 1% *C. viscidiflorus* 1%, *Symphoricarpos rotundiflorus* 2%, *Paxistima myrsinites* 1%, *Juniperus communis* 1%), Total forb cover 10% (*Lupinus* spp. 5%, *Artemisia frigida* 1%, *Potentilla hippiana* 1%, *Geranium richardsonii* 1%, *Androsace* spp. 1%, *Erigeron* spp. 1%, *Descurainia incisa* 1%, *Penstemon* spp. 1%, *Eriogonum umbellatum* 1%, *Castilleja* spp. 1%, *Achillea lanulosa* 1%, Erysimun spp. 1%, *Antennaria* spp. 1%, *Epilobium* spp. 1%, *Solidago* spp. 1%, *Boechera* spp. 1%); total grass cover 40% (*Festuca arizonica* 30%, *Elymus elymoides* 1%, *Bouteloua gracilis* 1%, *Muhlenbergia montana* 1%, *Koeleria macrantha* 1%, *Muhlenbergia filiculmis* 1%, *Danthonia parryi* 1%).
18		May 7,1911	Quartz porphyry.
19		August 9, 1998	Plants in fine sandy loam soils on xeric rock outcrops and talus slopes (10% incline) with southeast aspect and open exposures at 9,800 ft. Habitat type is *Ribes cereum/Brickellia grandiflora* (rock outcrop and talus slope). Trace of tree cover, 1% shrub cover, forb cover 5%, graminoid cover 5%, trace of moss and lichen cover and total bare ground 89%. Associated species include: *Urtica gracilis*, *Brickellia grandiflora*, *Erigeron compositus*, *Festuca arizonica*, *Heterotheca villosa*, *Artemisia frigida*, *Senecio atratus*, *Chaenactis douglasii*, *Cystopteris fragilis*, *Muhlenbergia montana*, *Apocynum androsaemifolium*, *Ribes montigenum*, *Holodiscus dumosus*, *Rubus idaeus*.
20		July 27, 1998	On west-facing rockfall slopes (30% incline) and cliffs (100% incline) at 9,200 to 9,500 ft. Plants in full sun or partly shaded by other plants. Talus slopes and cliffs are sparsely vegetated with *Pseudotsuga menziesii* (10%), *Populus tremuloides* (1%), *Ribes cereum* (5%), *Festuca arizonica* (20%). Associated taxa include *Artemisia frigida* and *Rosa woodsii*.
21		June 19, 1939	Southern exposure, sun, in rock crevices (talus slope).
22		August 9, 1998	No information.
23		July 27, 1998	On volcanic (rhyolite?) rock outcrop in *Picea englemannii-Populus tremuloides* montane forest and on west-facing talus slopes. The slopes go down to a creek and pond with salamanders. Sites are xeric and open with shallow clay rocky soils. The rock outcrop covered with abundant lichen. Associated taxa include *Aquilegia coerulea*, *Mertensia* spp., *Festuca arizonica*, *Cryptgramma* spp., *Eremogone* spp. Elevation 10,300 ft.
24		July 12, 1998	A steep shady south-and south-east facing rocky slope (60% incline) above a creek dominated by aspen and *Picea engelmannii* with some bristle cone pine. Shady, xeric sites in sandy clay soils on volcanic-basalt rocks at 10,200 ft.
25	Saguache	June 23, 1992	Moist rocky site in stand of *Populus tremuloides* at approximately 10,800 ft.
26		July 14, 1991	On Crestone conglomerate of Sangre de Cristo formation on south-facing unstable talus slope in boulder crevices and in loose barren sliding soil and rocks near timberline with *Juniperus communis*, *Pinus aristata*, *Erigeron pinnatisectus*, *Pentaphylloides floribunda* at 11,800 ft.
27		March 5, 1905	No information.

Table 3. Species reported to be associates of *Draba smithii*. This is not an exhaustive list and represents only the observations that were made on herbarium sheets, in Colorado Natural Heritage Program element occurrence records, and in the literature.

	Forbs
Trees	
Alnus incana	*Achillea lanulosa*
Picea pungens	*Androsace* spp.
Pinus aristata	*Antennaria* spp.
Populus tremuloides	*Aquilegia coerulea*
Pseudotsuga menziesii	*Artemisia frigida* (sub-shrub)
Salix spp.	*Boechera* spp.
	Castilleja spp.
Shrubs	*Chaenactis douglasii*
Apocynum androsaemifolium	*Cryptantha weberi*
Brickellia grandiflora	*Crytogramma* spp.
Chrysothamnus nauseosus	*Cystopteris fragilis*
Chrysothamnus viscidiflorus	*Descurainia incisa*
Cornus stolonifera	*Epilobium* spp.
Holodiscus dumosus	*Eremogone* spp.
Juniperus communis	*Erigeron compositus*
Paxistima myrsinites	*Erigeron pinnatisectus*
Pentaphylloides floribunda	*Erigeron* spp.
Ribes cereum	*Eriogonum umbellatum*
Ribes montigenum	*Erysimum* spp.
Rosa woodsii	*Geranium caespitosum*
Rubus idaeus	*Geranium richardsonii*
Symphoricarpos rotundiflorus	*Gilia penstemonoides*
	Heterotheca villosa
Grasses	*Lupinus* spp.
Bouteloua gracilis	*Mertensia* spp.
Danthonia parryi	*Oreocarya weberi*
Elymus elymoides	*Penstemon* spp.
Festuca arizonica	*Potentilla hippiana*
Koeleria macrantha	*Senecio atratus*
Muhlenbergia filiculmis	*Solidago* spp.
Muhlenbergia montana	*Urtica gracilis*

arctic and the mountains of Asia and North America to the section Phyllodraba based on the abundance of cauline leaves. Other white-flowered species that have fewer cauline leaves such as *D. incana*, were placed in the Leucodraba section by Schulz (1927). The relationship between the presence of cauline leaves and reproductive system may be tenuous, but habitat conditions, growth habit, and flower size and color may all be linked to reproductive similarities. For example, speculation from Mulligan and Findlay's (1970) work suggests out-crossing may be more common in climates that are more conducive to insect activity, such as southern Colorado. Relatively large, conspicuous flowers may indicate an association with insect pollinators. However, it is not possible to make an accurate deduction as to the reproductive situation of *D. smithii*. Assumptions should be avoided and the consequences of all possible breeding systems should be considered when making management decisions.

If the species is primarily self-pollinating, that is inbreeding, populations may have low heterozygosity and a relatively high risk of succumbing to significant climate change or other perturbations such as introduction of disease or deleterious arthropods. However, on the positive side, fecundity will likely not be limited by pollen availability or pollinator activity, and seed set will be assured. Occurrences may thus be particularly genetically isolated, and populations may be only as large as the area within which seed can be dispersed.

If *Draba smithii* is a cross-pollinating species, that is an outcrosser, seed set relies on available pollen from other plants and adequate pollinator activity. Any reduction in pollinator abundance and/or activity may be detrimental. In addition, flower abundance, both of *D. smithii* and associated species, may influence successful seed set. The pollinator species assemblage may also be important.

It is likely that whatever the mode of reproduction, *Draba smithii* populations will be locally adapted. The two morphological forms observed support this supposition. Even though growth form morphology may be a consequence of differential gene expression caused by environmental cues, it is also likely that combinations of genes are intrinsically co-adapted (Templeton 1986). In the case of cross-pollinating species, a reduction in fitness may occur when plants from a remote site are introduced to a local population and out-breeding depression results. This is a particular concern if efforts are made to increase certain populations or introduce the species to new areas. The population size for out-crossing species may cover quite large areas. No evidence of hybridization between *D. smithii* and other species has been reported, although apparently hybridization is common among the *Draba*, even across ploidy levels (Brochmann et al. 1992).

Seed bank dynamics, that is, rates of recruitment, seed longevity in soil, seed germination rate, and size of the seed bank, are also not known. Apparently, seeds of all the species of mountain *Drabas* studied have exhibited some level of physiological dormancy that is broken by cold stratification (Baskin and Baskin 2001).

Demography

A simple life cycle diagram (**Figure 5**) is constructed from the information available. It is not known if mature, flowering individuals can revert to

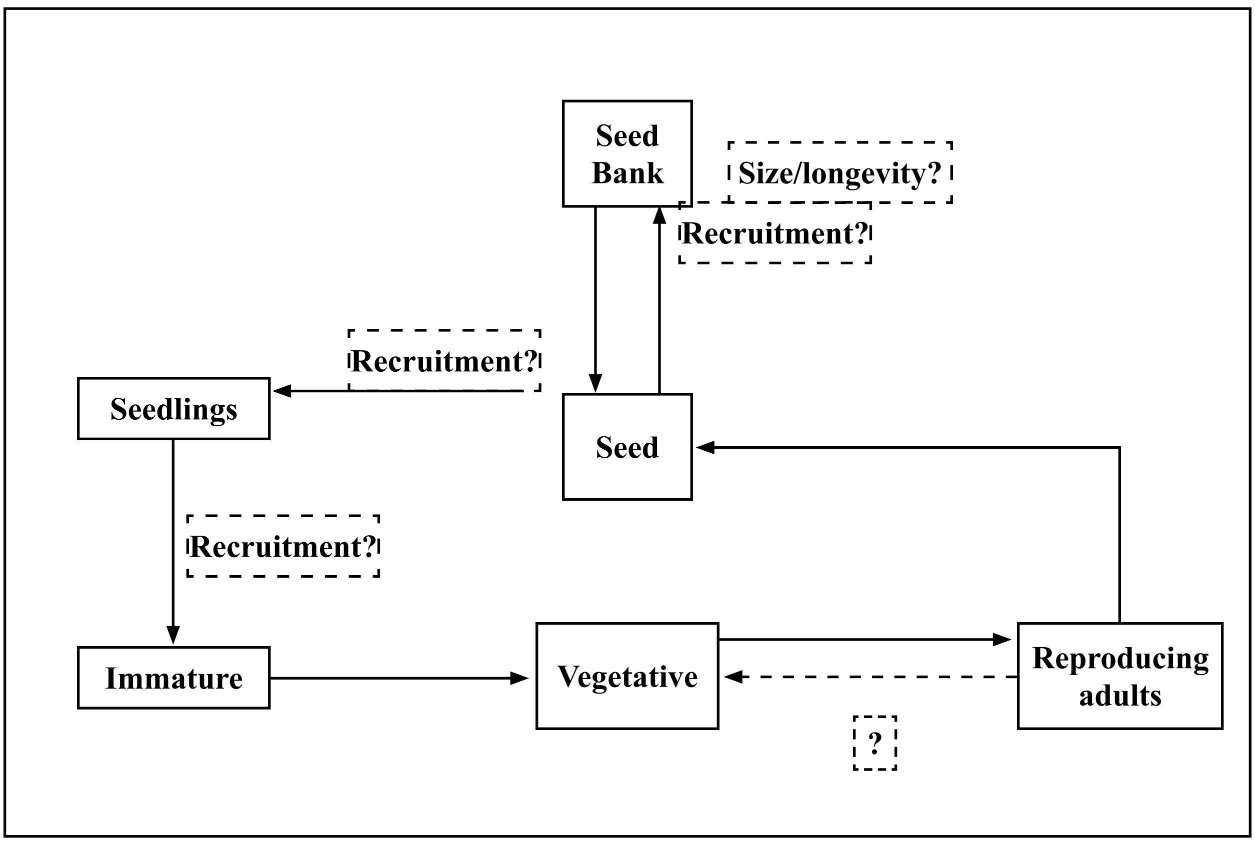

Figure 5. Life cycle diagram of *Draba smithii*.

a vegetative state in subsequent years or the extent to which the leafy basal rosettes turn over. Immature, or juvenile, individuals are included after the seedling stage to include the possibility that a minimum size must be achieved before flowering occurs. No studies have been undertaken to determine the demographic or genetic structure of *Draba smithii* populations. There are no data available to allow calculation of the equilibrium growth rate (λ) that integrates the effects of survival, growth, and fecundity of the different life history stages into a single parameter (Caswell 1989, Silvertown et al.1993).

It is not clear as to what constitutes a population of *Draba smithii*. To a great extent the definition depends upon the reproductive and seed dispersal systems. If cross-pollination occurs, any individuals within pollinator flight range can be expected to interact, and thus the potential size of a population may be quite large. Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m (range 70 to 631 m) from the nest to forage even when there appears to be plentiful food nearby. Honeybees apparently can regularly forage 2 km away from their hive (Ramsey et al. 1999). Pikas, which have been observed to eat the flowering stems of *D. smithii* (Rondeau and Cordova 1998 in Colorado Natural Heritage Program element occurrence records 2002), and possibly other herbivores may be responsible for some seed dispersal, potentially over a large area. However, the patchy nature of *D. smithii*'s spatial distribution suggests seed dispersal is often limited and localized around the parent plant.

The majority of *Draba smithii* plants at individual occurrences have been described as flowering or fruiting. Quantitative estimates of the numbers of individuals that remained vegetative and those that were fruiting were made at five occurrences. Between 10 and 40 percent of individuals were reported vegetative and 40 to 85 percent fruiting. On average 18 percent were vegetative and 82 percent reproductive (19 percent flowering and 63 percent with siliques). The preponderance of fruiting rather than flowering individuals was no doubt due to the time of year the surveys were made. The size and age of the vegetative plants were never estimated, so it is unknown whether any vegetative individuals were first year seedlings. The paucity, if not apparent absence, of seedlings may be due to high mortality rate or poor seed germination.

In a study of *Draba trichocarpa*, another perennial species, non-reproductive and reproductive individuals were stable, but the seedling mortality rate was very high (Moseley and Mancuso 1993). In long-lived perennials seed production may be low and the most important life cycle components are growth and survival of the adult plants (Silvertown et al. 1993). In this case, assets are allocated to favor the survival of the adult. However, in both *D. smithii* and *D. trichocarpa*, although considerable energy is expended towards reproduction, apparently few seedlings are observed. Moseley and Mancuso (1993) concluded that mature *D. trichocarpa* plants are relatively long lived but poor seedling recruitment, caused by a 73 percent mortality rate, poses significant limitations to population growth and longevity. Seed germination and seedling establishment are also very sensitive to environmental conditions.

Draba smithii populations also appear to be skewed in favor of reproductive adults. Considering the number of reproductively active individuals within any one population, *D. smithii* may be a relatively long-lived perennial that produces abundant fruit and potentially abundant seed in as many years as possible for storage in the soil seed bank. Periodical seed germination and seedling establishment may then occur during ideal environmental conditions. One particularly "good" year among several that are inappropriate for seedling establishment may thus sustain a small long-lived population. Abundant seed production in most years may circumvent the situation where conditions that are ideal for seedling establishment are immediately preceded by conditions that lead to poor seed fill. However, the longevity and viability of *D. smithii* seed are unknown.

Draba smithii does appear to exist in naturally small populations. Harper (1977) summarized ecological causes of small population size thus: "The carrying capacity of the site may be low; the available sites are few and separated by distances beyond the species' normal dispersal ability; the habitability of the site is of short duration because of successional displacement; colonization is in its early stages, and full exploitation of the site has not occurred." Considering the habitat and what is known of the life cycle, it is likely the first two statements particularly apply to *D. smithii*. Successional processes are likely limited by the substrate, and the rock faces and boulder environments can provide a stable habitat for a long-lived perennial. The current evidence suggests that *D. smithii* is a perennial species with attributes that are characterized as stress tolerant by Grime et al. (1988), or a k-selected species, one that has a long life span in relatively stable habitats, as characterized by MacArthur and Wilson (1967). However, the talus slope habitat will likely be in a state of frequent disturbance. How *D. smithii* has adapted to an unstable substrate has not been documented. The alternatives, which are not mutually exclusive, are that the plants can readily regenerate from seed or that *D. smithii* is functionally a geophyte and the roots and multi-headed caudex can regenerate after significant disturbance. In either case some level of disturbance may be tolerated, although not required.

No analyses of population viability have been documented. There are uncertainties, including threats associated directly and indirectly with human activities, which can only be mitigated by increasing both the number and the size of populations. Those uncertainties that are typically addressed in population viability analyses include elements of environmental stochasticity, demographic stochasticity, genetic stochasticity, and natural catastrophes (Shaffer 1981). The term "stochasticity" can be replaced by "uncertainty" (Frankel et al. 1995). The influences of the different types of uncertainties on *Draba smithii* may only be commented upon with little supporting quantitative data.

Environmental uncertainty lies in random, partly unpredictable, changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Demographic uncertainty relates to the random variation in survival and fecundity of individuals within a fixed population. Genetic uncertainties are associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations. Specific environmental uncertainties that affect survival and reproductive success of *Draba smithii* include variation in precipitation and, most likely, variable populations of arthropods (pollinators, herbivores, granivores) and certain herbivores such as pikas (see Community Ecology and Threats sections).

As mentioned in the previous section, the genetic isolation of each occurrence is unknown. Where occurrences of this species are small, less than 50 individuals, demographic uncertainty may be important (Pollard 1966, Keiding 1975). That is, chance events independent of the environment may affect the reproductive success and survival of individuals that, in very small populations, have a proportionally more important influence on survival of the whole population. It is therefore important to understand the associations between relatively small and isolated occurrences. Through out-crossing, spatially disjunct groups may have high levels of dispersal and gene flow between them. However, because bees are density-dependent foragers, it is unclear how much genetic exchange is between, rather than within, small patches of plants, especially during conditions of low flower production such as drought. If there is little genetic exchange among small occurrences, then there may be considerable genetic variation between populations but little variation within populations, leading to vulnerability to genetic uncertainty. Locally endemic species tend to exhibit reduced levels of polymorphism (Karron 1991) that may imply a reduced robustness against environmental uncertainty. However, while rare species have statistically less genetic variation than their widespread congeners, there is a large range in values (Gitzendanner and Soltis 2000). In fact, some rare species exhibit levels of diversity equal to, or exceeding, that of widespread congeners (Gitzendanner and Soltis 2000). In addition, many rare species that have evolved in isolated small populations do not show ill effects of inbreeding depression of fragmented, naturally abundant species (Barrett and Kohn 1991). Genetic evaluation studies would clarify the genetic vulnerability of *Draba smithii*.

Community ecology

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used extensively to describe the conditions of animals but may also be applied to describe the condition of plant species (Andrewartha and Birch 1984). Those components that directly impact *Draba smithii* make up the centrum, and the indirectly acting components comprise the web (**Figure 6** and **Figure 7**). Unfortunately the information necessary to make a comprehensive envirogram for *D. smithii* is unavailable. The resource envirogram is constructed to outline some of the components that appear to directly impact the species. They are generally speculative factors that should be tested in the field. Dashed boxes indicate their speculative nature. Malentities are also poorly understood. The anthropogenic malentities only apply to a few of the current occurrences but are placed within complete boxes in the scheme. Habitat destruction appears to be the ultimate consequence of the recognized threats. They are discussed more fully in the following Threats section.

It is not known how palatable *Draba smithii* is to herbivores in general, but at one occurrence pikas appeared to especially target the fruiting stems (Rondeau and Codova (1998) in Colorado Natural Heritage Program element occurrence records received in 2002). Pikas, small round-eared, rabbit-like animals that not only eat vegetation, but also collect and dry it in

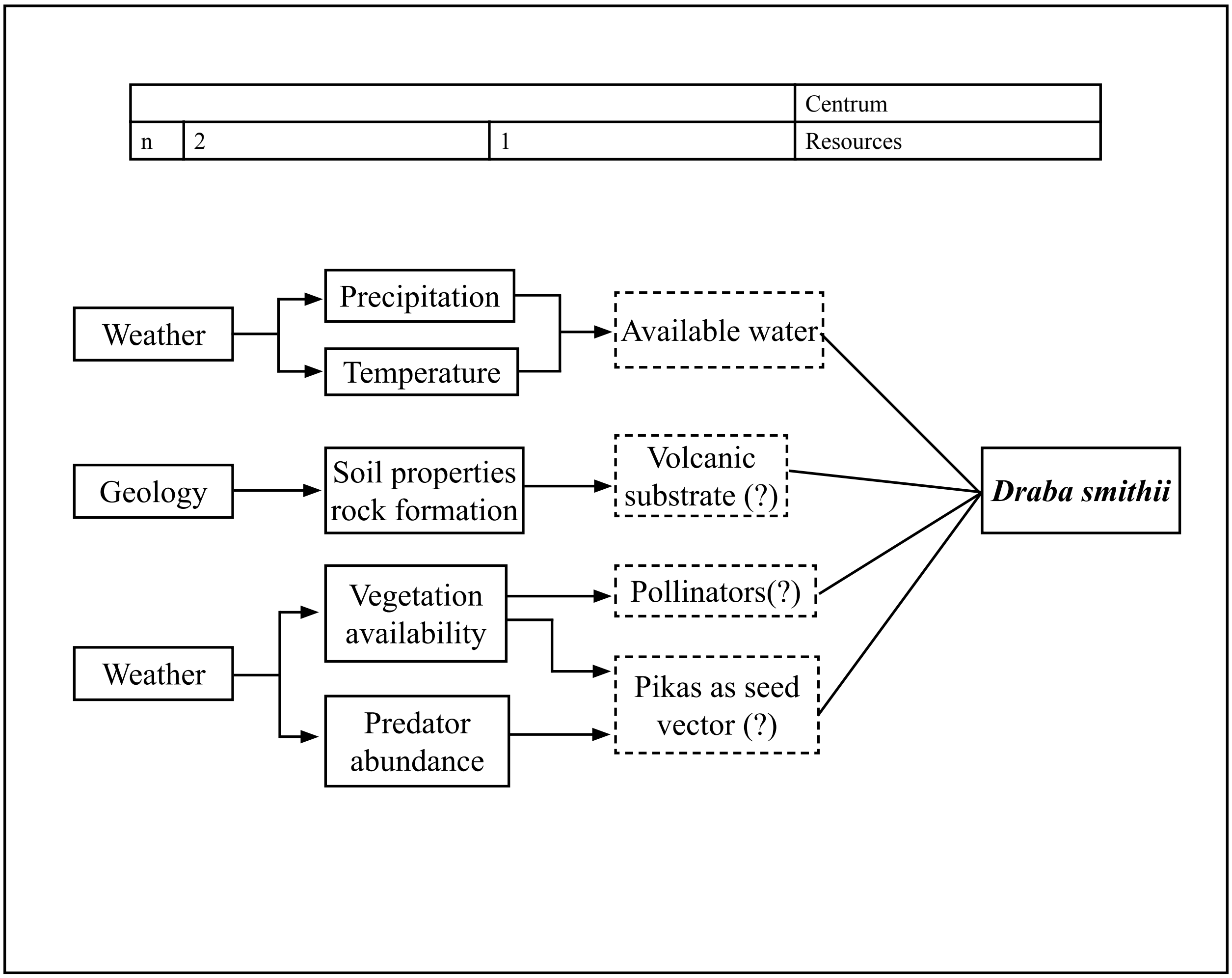

Figure 6. Envirogram of resources of *Draba smithii*.

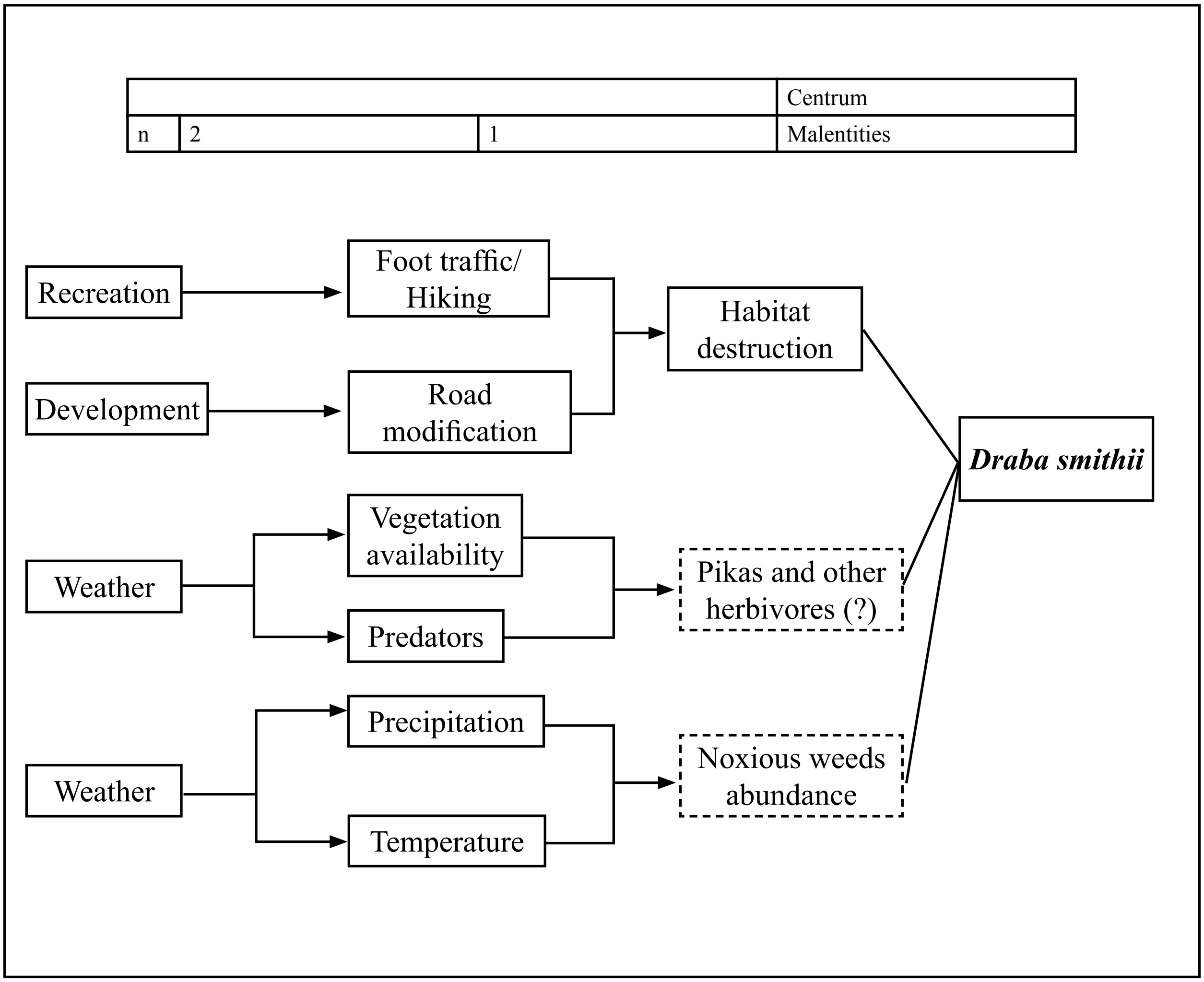

Figure 7. Envirogram of malentities of *Draba smithii*.

"haystacks" among rocks at one location before storing it in underground burrows, may be a resource as well as a malentity. Although too much activity early in the season may reduce mature seed production, pikas food collection and storage behaviors may be important in seed dispersal. Pollinators may be important resources if cross-pollination is important. Fundamentally, pollinators may be essential for seed production or, if the species is self-compatible with limited out-crossing, they may aid gene flow and promote heterozygosity among occurrences. Flies or bees may be pollinators. Bees are density dependent foragers and will avoid populations where the reward (i.e. flowers) is potentially low (Heinrich 1976, Thomson 1982, Geer and Tepedino 1993). This may be a concern for *D. smithii*, as it grows in generally small patches in areas of low vegetation cover. Pollinators, as a resource, were also discussed in the Reproductive Biology and Autecology section. Interactions between arthropods, other than pollinators, and their relationship to specific plant species are generally not well documented, and their impact on *D. smithii* is not known. No fungal or other microbial diseases have been reported.

CONSERVATION

Threats

The majority of known occurrence sites are on USDA Forest Service land (25 of approximately 27 known occurrences; **Table 1**), and therefore management decisions made by that agency can potentially have a substantial effect on the entire population. Anthropogenic threats appear to be localized both on and off National Forest System lands. The greatest threat is habitat modification through causes that differ depending upon the site.

Recreational activities may be a potential problem at some occurrences (Burt 1999 in Colorado Natural Heritage Program record 2002). For example, plants were directly adjacent to a trail in the Sangre de Cristo Mountain Range in the Rio Grande National Forest that is heavily used by hikers visiting the Great Sand Dunes National Monument. Off-trail scrambling was reported likely to impact the small population at that site.

Development is another specific threat to at least one population. Occupied habitat along a short stretch of the East Fork Valley access road is vulnerable to any work along the road shoulder. Piano Creek Ranch Resort had intended to widen the road. Such work would most certainly have significantly and negatively impacted the *Draba smithii* population that grows very close to the existing road. As of October 2001 this threat appears to have receded, as the plans for the resort and associated road modifications have been postponed (Pearson personal communication 2002, San Juan Citizen Alliance 2002). Development projects on land managed by the USDA Forest Service are often associated with road, trail, and campground maintenance and improvement. There is no information on the potential impacts of such activity on the *D. smithii* population.

Draba smithii grows in regions that experience fire, although fire is likely a low to medium level threat because the species' rock and talus habitats are generally natural refuges. However, fire can deleteriously affect otherwise inaccessible rock dwelling species, for example *Perityle cernua*, either by direct heat or, possibly, by intense smoke (Ladyman 1998).

Palatability to herbivores is largely unknown. Pikas were noted to be voraciously consuming the fruiting stems at one occurrence (Rondeau and Codova (1998) in Colorado Natural Heritage Program element occurrence records received in 2002). The impacts of other herbivores such as arthropods, rodents, and livestock have not been reported. Patches of *Draba smithii* that are accessible to any herbivore are potentially vulnerable. Specifics of the potential vulnerability of occurrences on land managed by the USDA Forest Service are not available.

The potential threats by invasive plant species would appear minimal, as the immediate habitat of *Draba smithii* is relatively slow to be invaded by the currently known noxious weeds. Nonetheless, because of the potential for new weed species, high vigilance should be practiced for all habitats, even though the level of concern is low at the present time. In addition, although non-vascular plants are not noted for invasive behavior the potential for allelopathic, or physical, interactions with certain species should not be discounted.

In one scenario of global climate change based on the United Kingdom Hadley Center's climate model (HadCM2), Colorado will experience higher year-round temperatures and greater precipitation in spring, fall, and winter. Grasslands will expand at the expense of forests (U.S. Environmental Protection Agency 1997). Although the trend in average precipitation over the last 100 years for Colorado has been generally one of decline, an increase has been reported in the range of *Draba smithii* (U.S. Environmental Protection Agency 1997). It is not clear how *D. smithii* would tolerate warmer temperatures but, considering it can grow in seep areas, more precipitation, as long as the areas were not flooded, would seem tolerable or even beneficial. In addition, the period of fecundity appears fairly flexible, and the plant may be able to adjust to many changes. However, the same manifestations of climate change may also have some indirect effects. A decrease in predators (owls, snakes, and coyotes) of species such as pikas and rodents may have a significant effect on all plants that provide a source of food for those creatures. In addition, perturbations on both detrimental and beneficial arthropod populations cannot be predicted. The importance of either specific or general pollinators to *D. smithii* sustainability is unknown.

Conservation Status of the Species in Region 2

The limited available evidence suggests that populations of this regional endemic are persistent in Region 2 of the USDA Forest Service. Most of the information on this species is from relatively casual observation and therefore is subject to error. There appears to be adequate potential habitat for this species under current management practices although our ignorance of the reasons why it has a patchy spatial distribution indicates that we may overestimate "potential habitat" (see Distribution and Abundance section). There are no specific conservation management plans for this species. This species may have a low priority for management considerations because there appears to be relatively few or only localized threats. However, only more surveys and monitoring studies can confirm that this is the true situation. Because there are such small numbers of plants at few occurrences, any manner of localized disturbance or event could constitute a significant threat to a relatively large proportion of the total population.

Management of the Species in Region 2

Implications and potential

Draba smithii is endemic to an area in Region 2 that includes three national forests, all in the southern part of Colorado. Because of its relatively small range, with a little more information on this species' distribution and abundance, a coordinated conservation strategy could be developed. In such a coordinated plan, the condition of each occurrence can be evaluated in the context of the whole population. Documented plans and strategies provide an excellent guide and a stable source of information that allows management continuity during staff turnover.

The mode of reproduction and population size has implications as to management considerations (Barrett and Kohn 1991). If populations are small and genetically isolated, maintaining existing levels of genetic variability may mean that each occurrence, and each individual within an occurrence, assumes greater importance than if populations were large and genetically similar. Generalizations and deductions based on studies of species other than *Draba smithii* are subject to error. However, when considering which populations to protect it is important to remember that rare species often exhibit genetic differences between populations. Small populations may be genetically depauperate as a result of changes in gene frequencies due to inbreeding, or founder effects (Menges 1991) but the value of small populations should not be belittled. For example, alleles that were absent in larger populations were only found in a small population of *Astragalus osterhouti* (Karron et al. 1988). Therefore, in order to conserve genetic variability, in the absence of genetic (DNA) data, it is likely most important to conserve as many populations as possible in as large a geographic area as possible and to keep in mind that a larger population is not automatically better. In addition, in order to maintain as many potential ecotypes as possible, a representative range of elevations, from 2,300 to 4,000 m, may also be particularly important to consider when planning a conservation strategy.

Tools and practices

Inventory and monitoring populations and habitat.

Species inventory. There have been relatively little occurrence data collected on this species. Surveys should always be conducted at an appropriate time of year, and in the case of *Draba smithii*, this is when the plant has flowers and preferably fruits (early June through July). The presence of flowers is very useful as their color helps in easy detection of plants from a distance. The patches of plants should be carefully examined to determine that individuals, not just stems, are recorded. The prolific branching nature of the caudex may give the impression that there are multiple individuals where only one exists.

The current "Field survey form for endangered, threatened or sensitive plant species" used by the Gunnison National Forest (Austin 2001) and the Colorado Natural Heritage Program (see References section for Web site address) both request the collection of data that is appropriate for inventory purposes. An additional formal "space" on the data collection form to show a diagrammatic representation of the occurrence may be useful, especially if an aggregated spatial pattern, patch structure, or location among boulders needs further explanation. The number of individuals, the area they occupy, and the apparent potential habitat are important data for occurrence comparison.

Habitat inventory. Habitat inventories have not been reported. At the current time, potential habitat is best defined as habitat that from casual observation appears suitable for the species, but which is not occupied by it. The information to perform a critical and accurate analysis of habitat requirements is currently unavailable. Occupied habitat descriptions suggest that habitat requirements are relatively broad. However, only a very little of the "potential" habitat is currently occupied, and *Draba smithii* may have more specific habitat requirements than what are known. The importance of seasonal water availability, rock type, and perhaps the extent of its weathering should be particularly considered and noted when surveying for *D. smithii* populations. Habitat inventory in the absence of plants cannot be made.

Population monitoring. There have been no monitoring studies for *Draba smithii*. This species grows in small patches in crevices and ledges of rock or on talus slopes. These individual patches may be monitored and demographic studies undertaken using permanent plots. Permanent plots would be very useful in determining population structure, life history of individual plants, and longevity of individual patches. However, if the goal is to monitor sub-samples in order to detect changes in a larger population over a long time period, such as observing the effects of disturbance on the talus slopes or changing canopy cover, permanent monitoring plots will run into the problems associated with auto-correlation (Goldsmith 1991). To minimize such problems, monitoring protocols for species with a spatially aggregated, or patchy, distribution have been described by Elzinga et al. (1998) and Goldsmith (1991). Lesica (1987) outlined a straightforward, relatively simple protocol for monitoring non-rhizomatous, perennial plant species that also generates important demographic data.

Photopoints and photoplots are very useful in visualizing changes over time especially in places such as cliff faces or steep talus slopes that are relatively inaccessible and/or can easily be disturbed by monitoring activities. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides or even hardcopies as in 50 years time the technology to read memory sticks and CDs may no longer be available.

Yearly monitoring is very useful if population size and/or vigor exhibit a high degree of year-to-year variation. This is particularly the case for many annual species or herbaceous perennial species that possess underground organs that undergo prolonged dormancy. For species that exhibit more stable aboveground populations, monitoring may occur at longer intervals. The appropriate interval will be most successfully determined after a period of yearly monitoring. It is very important to clearly define the goals of any monitoring plan and to identify the methods of data analyses before the beginning of the project. The time commitment per year will depend on the protocols adopted, the skill of the surveyor, and the distance between monitoring plots.

Habitat monitoring. Habitat monitoring in the absence of plants for this species is non-trivial because the exact conditions for its survival are not well-defined (see Habitat inventory). When plants are present, habitat conditions should always be recorded as part of the population monitoring protocol. Important observations include the associated species present, the micro-environment (moist or xeric, shaded or sunny, aspect, slope), and the substrate conditions. Land use and its intensity, for example the type of recreation practices and livestock stocking rates, and whether or not there is evidence of such activities, should also be recorded. An easily accessible documented history of such information may be valuable in the future, when management plans are revised. Surveys for invasive species and weed management programs are always valuable in any habitat monitoring plan.

Information Needs

Relatively little is known about the life history and distribution of *Draba smithii*. It appears to be a naturally rare species that occurs in small patches. Occurrences are relatively widely scattered within the total range of the species, and more surveys examining areas between known occurrences would clarify its rarity. Information on habitat requirements suggests that *D. smithii* has a relatively low specificity in habitat requirements. It occupies both relatively very stable habitats, namely crevices and ledges on rock faces and boulders, and also unstable talus slopes that are given to periodic disturbance. It grows in both open and shaded sites with south, east, and west aspects, and it appears to grow equally well in xeric and wet conditions. This latter observation should be examined further as subtleties in wet conditions, for example seasonal wetness or water collection sites, might contribute to the patchy and rare nature of *D. smithii*.

More knowledge of the reproductive mechanism, demographics, and genetic structure of the species rangewide, as well as habitat requirements, would help in formulating management plans for *Draba smithii*. Potential population size, genetic vulnerability, and susceptibility to pollinator decline all depend on the reproductive system. Therefore, the reproductive system, whether it is inbreeding, out-crossing, or self-incompatible as well as what the relevant pollinator species are, is an important consideration. Colonies of five or six individuals on four or five adjacent boulders or rock faces are commonly reported. The interactions between these patches and the longevity of individuals are unknown. Understanding the patch dynamics of this species may help in understanding the distribution and infrequent nature of the species.

Knowledge of the genetic structure of populations and differences between the sub-populations would determine the extent of genetic homogeneity. It would also provide information on the genetic vulnerability of *Draba smithii* as well as indicate the importance of the different populations to maintaining genetic diversity. An analysis of the different morphological types (see Reproductive Biology and Autecology section) should be included within such a study.

With the information currently available, it is difficult to predict the effects of threats, such as multiple herbivore pressure, prolonged drought, and successive fires, or the amount of disturbance that this species can tolerate. A long-term monitoring study would answer many questions and provide information to formulate the best management plans.

Information needs may be summarized as follows:

- ❖ Make additional inventories to clarify the rarity of the taxon.
- ❖ Monitor populations to determine their stability.
- ❖ Critically determine its habitat requirements.
- ❖ Determine the reproductive system.
- ❖ Determine the extent of genetic heterogeneity.

Definitions

Allelopathic. The release of a chemical substance by one organism, which that acts on the growth or development of another organism.

Caudex. The persistent, often woody base of an otherwise herbaceous annual stem (Harrington and Durrell 1986).

Cauline. Of , or on, the stem. Such as "cauline leaves", this means leaves that are on the stem.

Geophyte. A land plant that survives an unfavorable period by means of an underground food-storage organ.

Heterozygosity. The presence of different alleles (forms of a given gene) at a particular gene locus (Allaby 1992).

Holotype. A single specimen that was designated as the type of the species by the original author at the time the species name and description was published.

Phenology. The study of the impact of climate on seasonal occurrences, for example the date of flowering, and the periodically changing form of an organism, for example the development of a seedling into a sapling and then into a tree (Allaby 1992).

Ranks. NatureServe and the Heritage Programs Ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm). G2 indicates *Draba smithii* is "imperiled globally because of rarity (6-20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range (endangered throughout its range)." S2 indicates it is "imperiled in the nation or subnation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000)".

Section. In North America the species in the genus *Draba* and *Erophila* were divided into sections to facilitate classification and identification (Schulz 1927).

Stellate hairs. Hairs with branches radiating from a central point making them look star-shaped.

Commonly Used Synonyms of Plant Species

Commonly used synonyms of plant species (Kartesz 1994) mentioned in this report. The reference in parenthesis refers to a Flora in Region 2 in which the synonym is used:

Arenaria spp.	*Eremogone* spp. (Weber and Wittman 2001a)
Cryptantha weberi	*Oreocarya weberi* (Weber and Wittman 2001b)
Cornus stolonifera	*Swida sericea* (Weber and Wittman 2001a)
Gilia penstemonoides	*Aliciella penstemonoides* (Weber and Wittman 2001a)
Pentaphylloides floribunda	*Potentilla fructicosa* (Harrington 1964)
Senecio atratus	*"Senecio" atratus* (Weber and Wittman 2001b)

References

Allaby, M. 1992. The concise Oxford dictionary of Botany. Oxford University Press, New York, New York.

Allred, Kelly. New Mexico State University, Las Cruces, New Mexico. E-mail communication. July 2002.

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web: more on the distribution and abundance of animals. University of Chicago Press, Chicago, Illinois.

Austin G. 2001. USDA Forest Service Field Survey form for Endangered, Threatened or Sensitive Plant Species - Gunnison National Forest. Unpublished report. Gunnison National Forest, Colorado.

Bailey, R.G., P.E. Avers, T. King, W.H. McNab. 1994. Ecoregions and subregions of the United States (map). USDA Forest Service, U.S. Geological Survey, Reston, Virginia.

Barrett, S.C.H. and J.R. Kohn. 1991. Genetic and evolutionary consequences of small population size in plants: Implications for conservation. Pp. 3-30 *in*: D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, New York.

Baskin, C.C. and J.M. Baskin. 2001. Seeds – ecology, biogeography, and evolution of dormancy and germination. Academic Press, New York, New York.

Brochmann, C., B. Stedje, and L. Borgen. 1992. Gene flow across ploidal levels in *Draba* (Brassicaceae). Evolutionary Trends in Plants 6(2) 125-134.

Caswell, H. 1989. Matrix population methods. Sinauer Associates, Inc., Sunderland, Massachusetts.

Colorado Native Plant Society. 1997. Rare Plants of Colorado. 2^{nd} edition. Falcon Press Publishing Co., Helena, Montana.

Colorado Natural Areas Program. RaJadero Canyon Colorado Natural Area. Internet Web site: http://parks.state.co.us/cnap/Natural_Areas/NA%20pages/rajadero.htm [Accessed January 2002].

Colorado Natural Heritage Program element occurrence records. Received from Colorado Natural Heritage Program, Fort Collins, Colorado. February 2002.

Dick-Peddie W.A. 1993. New Mexico Vegetation – past, present, and future. University of New Mexico Press, Albuquerque, New Mexico.

Elliott, B. and R.L. Hartman. 2000. A general floristic survey of the San Isabel and Rio Grande National forests south of the Arkansas and South Arkansas rivers. Unpublished report of the Rocky Mountain Herbarium, University of Wyoming, Laramie, Wyoming, U.S.A and the U.S. Forest Service San Isabel and Rio Grande National Forests, Colorado.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1. U.S. Department of Interior, Bureau of Land Management, Denver, Colorado.

Erhard, D. 1994. Threatened, Endangered, and Sensitive Plant Guide, Rio Grande National Forest. Limited issue publication. U.S. Forest Service, Rio Grand National Forest, Monte Vista, Colorado.

Erhard, Dean. U.S. Forest Service, Rio Grande National Forest, Colorado. Telephone and e-mail communications. February, March, and June 2002.

Frankel O.H., A.H.D. Brown, and J.J. Burdon. 1995. The conservation of plant biodiversity. Pp. 127. Cambridge University Press, New York, New York.

Geer, S.M. and V.J. Tepedino. 1993. Breeding systems of the rare heliotrope milkvetch (*Astraglus montii* Welsh: Fabaceae) and two common congeners. *In*: R. Sivinski and K. Lightfoot, editors. Proceedings of the southwestern rare and endangered plant conference. Based on the conference held March 30-April 2, 1992. Misc. Publication No. 2. New Mexico Forestry and Resources Conservation Division, Energy, Mineral and Natural Resources Department, Santa Fe, New Mexico.

Gitzendanner, M.A. and P.S. Soltis. 2000. Patterns of genetic variation in rare and widespread plant congeners. American Journal of Botany 87(6):783-792

Goldsmith, F.B. 1991. Monitoring for Conservation and Ecology. Chapman and Hall, New York, New York.

Grime, J.P., J.G. Hodgson, and R. Hunt. 1988. Comparative plant ecology – a functional approach to common British species. Allen and Unwin, Inc., Winchester, Massachusetts.

Harper, J.L. 1977. *Population Biology of Plants*. Academic Press, London, England, United Kingdom.

Harrington, H.D. 1964. Manual of the plants of Colorado. 2nd edition. Sage Books, Denver, Colorado.

Harrington, H.D. and L.W. Durrell. 1986. How to identify plants. Swallow Press, Athens, Ohio.

Heinrich, B. 1976. The foraging specializations of individual bumble bees. Ecological Monographs 46:105-128.

Hitchcock, C.L. 1941. A revision of the Drabas of Western North America. University of Washington Publications in Biology 11:1-132.

Johnston, B.C. 1987. Plant associations of Region 2: potential plant communities of Wyoming, South Dakota, Nebraska, Colorado, and Kansas. 4th edition. USDA Forest service, Rocky Mountain Region R2-ECOL-87-2, Lakewood, Colorado.

Karron J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. Pages 87-98 *in*: D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, New York.

Karron, J.D., Y.B. Linhart, C.A. Chaulk, and C.A. Robertson.1988. Genetic structure of geographically restricted and wide-spread species of *Astragalus* (Fabaceae). American Journal of Botany. 75:1114-1119.

Keiding, N. 1975. Extinction and exponential growth in random environments. Theoretical Population Biology 8: 49-63.

Ladyman, J.AR. 1998. Post Fire Ecological Studies in the Organ Mountains – Monitoring sensitive species and vegetation. Unpublished document prepared for and submitted to the Army Corps of Engineers, Fort Bliss, El Paso, Texas.

Lesica, P. 1987. A technique for monitoring nonrhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7(2):65-68

MacArthur, R.H. and E.D. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey.

McNab, W.H. and P.E. Avers 1994. Ecological subregions of the United States: Section descriptions. Administrative Publication WO-WSA-5. U.S. Department of Agriculture Forest Service. Washington, DC.

Menges, E.S. 1991. The application of minimum viable population theory to plants. Pages 45-61 *in*: D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, New York.

Moseley, R.K. and M. Mancuso. 1992. Long-term demographic monitoring of two Stanley Basin endemics, *Draba trichocarpa* and *Eriogonum meledonum*. II. Second-year results. Conservation Data Center, Nongame/Endangered wildlife program. Idaho Department for Fish and Game, Boise, Idaho.

Mulligan, G.A. 1970. Cytotaxonomic studies of *Draba glabella* and its close allies in Canada and Alaska. Canadian Journal of Botany 48:1431-1437.

Mulligan, G.A. 1976. The *Draba* in Canada and Alaska: key and summary. Canadian Journal of Botany 54:1386-1393

Mulligan, G.A. and J.N. Findlay. 1970. Sexual reproduction and agamospermy in the genus *Draba*. Canadian Journal of Botany 48:269-270.

NatureServe, Arlington, Virginia. Global Rank updated 7 May 1996, National Heritage Status Rank updated 13 May 1997. Internet Web site: http://www.natureserve.org/explorer/ [Accessed February 26, 2002].

New York Botanical Garden Herbarium. Botanical Science Division, Bronx, New York, USA. Internet Web site: http://www.nybg.org/bsci/herb/ [Accessed February 2002]

Osborne, J.L., S.J. Clark, R. Morris, I. Williams, R. Riley, A. Smith, D. Reynolds, and A. Edwards. 1999. A landscape-scale study of bumble bee foraging range and constancy, using harmonic radar. Journal of Applied Ecology. 36:519-533.

Pearson, Mark. San Juan Citizens Alliance, Pagosa Springs, Colorado. E-mail communication. July 2002.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Pollard, J.H. 1966. On the use of the direct matrix product in analyzing certain stochastic population models. Biometrika 53:397-415

Ramsey, G., C.E. Thompson, S. Neilson, and G.R. Mackay. 1999. Honeybees as vectors of GM oilseed rape pollen. *In*: P.J.W. Lutman, editor. Gene flow and Agriculture: Relevance for Transgenic Crops. BCPC Symposium Proceedings no.72.

Redders, Jeff. San Juan National Forest, U.S. Forest Service, Telephone communication. 2002.

Rollins, R.C. 1993. The Cruciferae of continental North America, systematics of the mustard family from Artic to Panama. Stanford University Press, Stanford, California.

Ryke, N., L. McMartin, and D. Winters. 1993. Threatened, endangered, and sensitive species list for the Pike and San Isabel national forests and Comanche and Cimarron grasslands. August 30.

San Juan Citizens Alliance. East Fork Update — June 12, 2000. Internet Web site: http://www.sanjuancitizens.org/eastfork/june00update.shtml [Accessed February 2002]

Schulz, O.E. 1927. Cruciferae – *Draba* et *Erophila*. Das Pflanzenreich IV. 105:177.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-134.

Silvertown, J., M. Franco, I. Piasanty, and A. Mendoza. 1993. Comparative plant demography – relative importance of life cycle components to the finite rate of increase in woody and herbaceous perennials. Journal of Ecology. 81:465-476.

Spackman, S.B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, The U.S. Forest Service, and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, Colorado.

Templeton, A.R. 1986. Coadaptation and outbreeding depression. *In*: Conservation Biology: The science of scarcity and diversity, ed. M.E. Soule, pp 105-116. Sinauer, Sunderland, Massachusetts.

Thomson, J.D. 1982. Patterns of visitation by animal pollinators. Oikos 39:241-250.

Tweto, O. 1978. Geologic map of Colorado. U.S. Geological Survey, Denver, Colorado.

USDA Forest Service. 1991. Land and Resource Management Plan and Final Supplement to the Environmental Impact Statement. Grand Mesa, Uncompahgre, and Gunnison National Forests. USDA Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests, Delta, Colorado.

USDA Forest Service. 1995. Title 2600 - Wildlife, Fish, and Sensitive Plant Habitat Management. USFS Forest Service Manual, Amendment No. 2600-95-7. U.S. Department of Agriculture, Washington, D.C.

USDA Forest Service. 1996. The Revised Land and Resource Management Plan for the Rio Grande National Forest. Record of Decision. November 7 1996. Unpublished Document. Rio Grande National Forest, Monte Vista, Colorado. Internet Web site: http://www.fs.fed.us/r2/riogrande/planning/plan/planchap1.pdf.

USDA Forest Service. 1999. Establishment Record for Osborn Mountain Research Natural Area within Bridger-Teton National Forest, Sublette County, Wyoming. Unpublished document. Bridger-Teton National Forest, Sublette County, Wyoming.

USDA Forest Service. 2003. Forest Service Manual FSM 2600 – Wildlife, fish, and sensitive plant habitat, Chapter 2670 – threatened endangered and sensitive plants and animals. Supplement No.: 2600-2003-1, Effective Date: December 1, 2003. Rocky Mountain Region (Region 2) Denver, Colorado.

U.S. Environmental Protection Agency. 1997. Climate Change and Colorado. United States Environmental Protection Agency publication. EPA 230-F-97-008f. Washington, DC.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants: Review of plant taxa for listing as endangered or threatened species. Federal register. September 30. 50CFR, Part 17, Vol. 58, No. 188, 51144-51190.

U.S. Fish and Wildlife Service. 1996. Endangered and threatened wildlife and plants; review of plant and animal taxa that are candidates for listing as endangered or threatened species. Federal Register. February 28. 50CFR, Part 17, Vol. 61, No. 40, 7596-7613.

Weber, W.A. and R.C. Wittman. 2001a. Colorado Flora, eastern slope. 3rd edition. University Press of Colorado, Boulder, Colorado.

Weber, W.A. and R.C. Wittman. 2001b. Colorado Flora, western slope. 3rd edition. University Press of Colorado, Boulder, Colorado.

Weber, William. University of Colorado, Boulder, Colorado. E-mail communication. August 2002.

Windham, M. University of Utah, Logan, Utah. Utah. E-mail communication. May 2002.

Windham, M.D. 2000. Chromosome counts and taxonomic notes on *Draba* (Brassicaceae) of the Intermountain west. 1: Utah and vicinity. Madrono 47 (1):21-28

LIST OF ERRATA

03/25/04 Added an illustration to the assessment and named it as **Figure 2**. Renamed all previous figures except for **Figure 1**.